CHAPTER 11

Concrete Flatwork

Section 11.1
Foundation Slabs

Section 11.2
Finishing Flatwork

Chapter Objectives

After completing this chapter, you will be able to:

- **Identify** the two types of foundation slabs.
- **Describe** foundation slab details and reinforcement.
- **Explain** how to place a slab.
- **List** forms of flatwork other than foundations.
- **Demonstrate** the steps in finishing flatwork.
- **Explain** how temperature extremes affect fresh concrete.

Discuss the Photo

Concrete Foundation The foundation of a building is placed in the first stage of construction. *Why do you think concrete is used for building foundations?*

Writing Activity: Descriptive Writing

Look around your school and a neighborhood that interests you. What types of structures do you see that are made with concrete? Write a one-paragraph description of at least two of these structures.

Chapter 11 Reading Guide

Before You Read Preview

Concrete slabs are widely used as the foundation for houses in mild climates. Choose a content vocabulary or academic vocabulary word that is new to you. When you find it in the text, write down the definition.

Content Vocabulary

- concrete flatwork
- frost depth
- monolithic slab
- independent slab
- subgrade
- lift
- fines
- screed
- bull float
- kneeboard

Academic Vocabulary

You will find these words in your reading and on your tests. Use the academic vocabulary glossary to look up their definitions if necessary.

- layer
- occurs
- adjusted

Graphic Organizer

As you read, use a chart like the one shown to organize terms and their definitions. Keep notes on how each product or process is used, adding rows as needed.

Term	Definition	Use
monolithic slab	A footing and a floor slab that are formed in one continuous pour	Used in warm climates where frost is not a problem Used in areas where termite infestations are common
kneeboard	Board measuring about 12" by 24" placed on the concrete to support the weight of the finisher	Allows the finisher to move from one area to another without stepping onto the fresh concrete

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Academic Standards

English Language Arts

Use different writing process elements to communicate effectively (NCTE 5)

Mathematics

Measurement: Apply appropriate techniques, tools, and formulas to determine measurements (NCTM)

Number and Operations: Analyze change in various contexts (NCTM)

Science

Earth and Space Science: Energy in the earth system (NSES)

Industry Standards

Foundation Systems

Concrete Forms and Flatwork

NCTE National Council of Teachers of English
NCTM National Council of Teachers of Mathematics
NSES National Science Education Standards

Section 11.1 Foundation Slabs

Foundation Slab Basics

What is a monolithic slab?

Concrete flatwork consists of flat, horizontal areas of concrete that are usually 5" or less in thickness. Flatwork is placed either directly on the ground or over compacted gravel or sand. Examples of flatwork include foundation slabs, basement floors, driveways, and sidewalks. Concrete flatwork must be contained by forms until it is strong enough to hold its shape without forms.

Once a slab has been placed, its top surface must be finished. This means that the surface must be smoothed, textured, or otherwise worked using a combination of hand and power tools. Then, steps must be taken to ensure that the concrete cures properly. Improper curing reduces the strength of the concrete and can cause various other problems, such as cracking.

Concrete flatwork is generally installed by subcontractors who specialize in this work. This chapter will provide a general introduction to the topic.

Flatwork is commonly used in residential construction for foundation slabs in houses built without a basement or a crawl space. In mild or warm climates, a foundation slab has these advantages:

- Excavation costs are reduced because very little earth must be removed.
- Extensive or complex formwork is not required.
- A concrete slab eliminates the need for a separate subfloor.
- Construction costs are lower.
- The concrete provides a solid base for concrete block walls, which are sometimes used in warm climates as the exterior walls of the house.

A foundation slab also has some disadvantages. The primary disadvantage is that utilities must be planned carefully and roughed-in in advance, as shown in **Figure 11-1**. Changes are very difficult once the slab has been placed.

Frostline, Moisture, and Soil

The foundation of a house must always be deep enough so that it rests on soil that is *below* the local frost depth. The **frost depth** is the depth in any climate below which the soil does not freeze. Frost depth is also called *frostline* or *freezing depth.* If moisture is in the soil beneath a foundation, it can actually lift the foundation when it freezes and expands. When the soil thaws, it will return to its

Figure 11-1 A Slab Under Construction
Planning Ahead Pipes for the rough plumbing are cast into the floor as the concrete is placed during pouring.

previous volume. This cycle of expansion and contraction is an important consideration in foundation design because the movement, called *frost heave*, can cause a foundation to crack.

The type of soil is another factor that can affect foundation design. Various types of soil, particularly those containing clay, tend to hold moisture. These are called *expansive soils*. Other soils, particularly those with a high sand content, do not hold moisture. They are sometimes called *free-draining soils*. Because expansive soils hold water and are unstable, they should be avoided under and around a foundation. The best soil to have under a foundation is one that drains freely.

Types of Foundation Slabs

There are two types of foundation slabs: monolithic and independent. The choice to use one or the other depends largely on climate and local custom. In both cases, the minimum thickness required by code is 3½". A thickness of 4" is more common.

A **monolithic slab** consists of a footing and floor slab that are formed in one continuous pour. It is also referred to as a unified slab, a thickened-edge slab, or a slab with a turned-down footing. The perimeter of the slab is thicker than the main area, as shown in **Figure 11-2A** on page 296. It is strengthened with rebar at the edges. The bottom of the footing should be at least 1' below the natural grade line and supported by solid, unfilled, well-drained soil. A monolithic slab is useful in warm climates where frost penetration is not a problem and where soil conditions are favorable. It is also preferred in areas where termite infestations are common.

An **independent slab**, also called a *ground-support slab*, is a slab that is used in areas where the ground freezes fairly deep during winter. The house is supported by foundation walls that extend to solid bearing below the frostline. The slab is then poured between the foundation walls. (Foundation walls are discussed in Chapter 10, "Foundation Walls.") After the foundation wall formwork has been removed, the slab can be placed. One method for laying this type of slab is shown in **Figure 11-2B** on page 296.

Slab Details

Slab details include support, formwork, drainage, and reinforcement. Always check local codes for requirements that relate to concrete slabs. This is especially important where earthquake hazards must be considered.

Support for Bearing Walls Exterior bearing walls are supported either by the thickened edge of the slab or by foundation walls. Beneath interior bearing walls, the slab may be thickened to provide the necessary support, as shown in **Figure 11-3** on page 297. This thickened area is like a footing. It should be strengthened with rebar. Unlike a standard footing, the thickened area is formed by a trench, not by formwork.

Formwork A slab foundation does not require much formwork. For a monolithic slab, builders often use lumber to form the slab edges. Foundation contractors may prefer reusable metal or wood forms. In any case, the outer edges of the forms must be braced to resist the pressure of the wet concrete. After the concrete has partially cured, the forms can be removed.

REGIONAL CONCERNS

Slab or Basement? Where winter temperatures are fairly mild, slab foundations are often more cost-effective than other types of foundations. This is because a slab does not require the deeper extensive excavation that is needed for basement foundations. Full basements are not common in mild climates for this reason.

Go to **glencoe.com** for this book's OLC for more information on regional concerns.

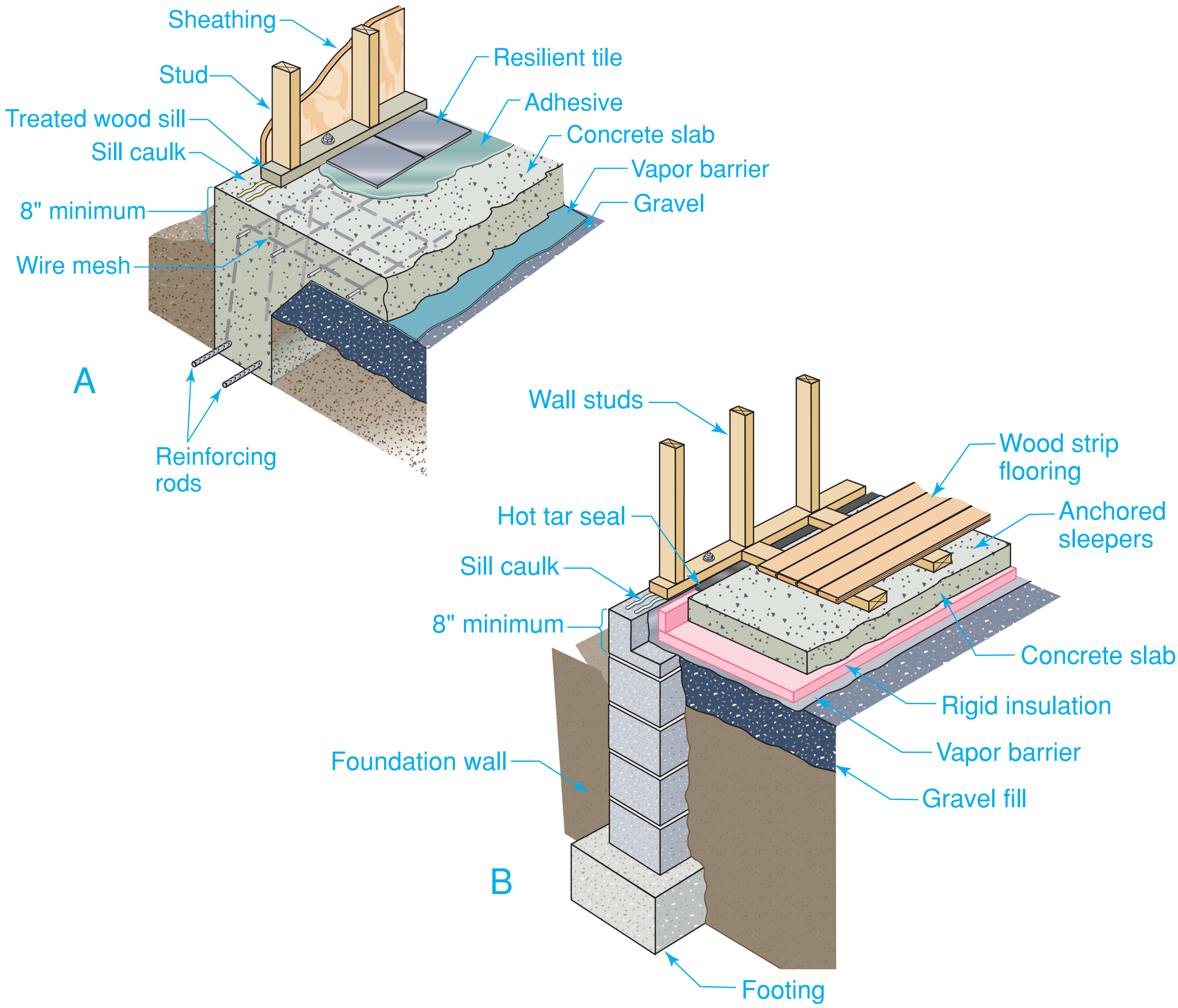

Figure 11-2 Types of Slab Foundations

Two Versions In a monolithic slab **A.**, the footing and the slab are placed at the same time. In an independent slab **B.**, the slab is placed after the foundation wall has been placed. *What are the main factors in choosing which type of slab foundation to use?*

Drainage The finish-floor level should be high enough above the natural ground level that finish grade around the house can be sloped away for good drainage. The top of the slab should be no less than 8" above the ground and the siding no less than 6".

A perimeter drain should be placed around the outside edge of the exterior wall footings, as shown in **Figure 11-4**. The drain helps keep ground moisture from wicking into the slab. Drain lines are not always required by code where the floor is located on fairly high ground, where subsoil is well drained, or in a very dry climate. Placement of the perimeter drain is similar to that for a full-height foundation (see Figure 10-6 in Chapter 10).

Reinforcement Metal reinforcement is often placed in a concrete slab to increase its tensile strength and reduce cracking. It also helps to prevent slabs from separating if they do crack. Welded-wire mesh keeps slabs from separating once the concrete has cracked. This reinforcement can consist of either rebar or welded-wire mesh fabric. Wire fabric is a grid of horizontal and vertical wires. It comes

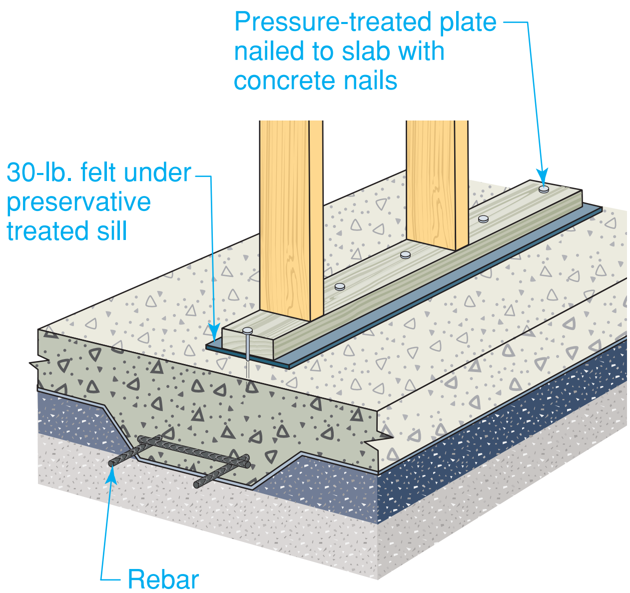

Figure 11-3 Support for Bearing Walls
Thickened Slab A foundation slab should be thickened beneath bearing walls to support the walls and prevent cracking.

Figure 11-4 Drainpipe
Perforated The holes in a drainpipe should face downward. They allow water in the pipe to be drained away.

in rolls and is cut to size at the site. Any reinforcement should be in place before the concrete is poured.

Code requirements for rebar vary, depending on the type of slab and its location. However, with a monolithic slab, either one #5 or two #4 bars should be located in the middle third of the footing's depth. Vertical lengths of rebar are sometimes added to reinforce the thickened portion of the slab. In earthquake areas, reinforcement is important. Local codes should be followed carefully.

Wire fabric should be placed near the center of the slab thickness. Contractors sometimes roll out the fabric over the excavation. They then use a rake or hook to pull it up into the concrete during the pour. However, this method makes it difficult to tell the exact position of the reinforcement. A more precise method is to support it on chairs. A *chair* is a small metal or plastic device that supports the wire fabric at a particular height (see Figure 8-10 in Chapter 8). Chairs are left in place as the concrete is poured. The IRC code requires the use of chairs when a slab is reinforced. The chair must support the reinforcement so that it will stay in place at or slightly above the center of the slab when the concrete is placed.

Insulation

In some climates, a foundation slab can feel uncomfortably cold if it is not insulated. The best insulation for slabs is rigid, nonabsorbent boards or sheets, such as extruded or expanded polystyrene. It can be placed around the perimeter of a monolithic slab, where the concrete is exposed to colder temperatures. For independent slabs, rigid insulation can be placed between the foundation walls and the edge of the floor slab, as shown in Figure 11-2B on page 296. Studies have shown that this edge insulation is important in reducing the amount of heat lost by conduction. Insulation may also be placed below the slab. This is especially important when radiant heating tubes are built into the slab (see Chapter 30, "Mechanicals").

Termite Protection Some areas of the United States have problems with termites. In these areas, special care must be taken to prevent termites from getting into the wood framing

Tim Fuller

above the concrete. One method is to chemically treat the soil before placing a slab. The chemicals, their strength, and the application methods are determined by local and state building officials. Their guidelines should be followed carefully.

Physical barriers, such as metal termite shields, should also be included. On monolithic slabs, shields should be located between the slab and the wall plate. For independent slabs, this barrier is continued to cover the gap between the slab and the foundation wall.

Where the chance of termite infestation is very high, the IRC building code prohibits the use of foam plastic insulation on the outside of foundation walls and beneath slabs below grade. This is because insects may tunnel through the insulation to reach wood framing.

Installing a Concrete Slab

A foundation slab is installed by foundation subcontractors. The following outlines the basic steps they use.

Preparing the Subgrade The **subgrade** is the earth below the slab. The subgrade must be uniformly compacted (pressed down) to prevent any uneven settlement of the floor slab. Uneven settlement is a common cause of cracks in concrete.

All organic matter, such as sod and roots, should first be removed and the ground leveled off. Any holes or cracks in the subgrade should be filled and compacted. Material for fill should be uniform. It should not contain large lumps, stones, or material that will rot. Any fill should be compacted in lifts no more than 6" deep. A **lift** is a uniform and fairly shallow layer of material. If fill is compacted in thicker layers, it may appear to be firm on the surface but it will not be uniformly firm. A *power tamper*, or plate tamper, is often used to compact fill, as shown in **Figure 11-5**. This tool is powered by a gasoline engine and guided by hand over the area. Areas that are difficult to reach with this equipment can be compacted with a hand tamper, shown in **Figure 11-6**.

Figure 11-5 Using a Power Tamper
Soil Compactor A power tamper can be used to compact the subgrade.

After any holes are filled, the entire subgrade should be thoroughly compacted by tamping or rolling. The finished subgrade should then be carefully checked for height and levelness. Any variations can create a slab of uneven thickness. When this occurs, the slab may not cure evenly, which is another common cause of cracking.

Figure 11-6 A Hand Tamper
Tight Spaces Compact coarse fill with a hand tamper.

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Soil cannot be properly compacted if it is too wet or too dry. You can get a rough idea of the proper moisture content of ordinary soils, except very sandy ones, by squeezing some in your hand. With proper moisture content, the soil will cling together but will not be *plastic* (clay-like) or muddy. If the soil is too dry, it should be sprinkled with water before compacting. If the soil is too wet, it must be allowed to dry.

Providing for Other Trades Electrical conduit, ducts for heating systems, and plumbing supply and waste lines can be placed in trenches cut in the subgrade. Care should be taken to protect water supply lines from freezing if the building will not be occupied during cold weather. Careful planning ensures that connections to these utilities can be made where specified on the building plans.

After a monolithic slab has been poured and partially finished, anchor bolts are inserted around the perimeter. Carpenters will use these to secure wall framing to the slab.

Preparing the Subbase Coarse fill should be placed over the compacted subgrade to form the subbase, or base course. This fill should consist of coarse slag, gravel, or crushed stone no more than 2" in diameter. The fill particles should be of uniform size to prevent them from packing together tightly. If necessary, the material should be sifted through a screen to remove any fines. **Fines** are finely crushed or powdered materials. The subbase, along with drainage pipes at the perimeter of the foundation, helps to drain water that might collect under the slab. When the slab is below grade, the subbase must be at least 4" thick. The fill should be brought to the desired grade and then thoroughly compacted.

Installing Vapor Retarder Water will not penetrate good quality concrete unless the water is driven by pressure (see Chapter 10, "Foundation Walls"). A properly constructed drainage system will prevent pressures from building up beneath a foundation slab. However, concrete can be penetrated by water vapor. If vapor passes through a slab, moisture can cause problems inside the house. For example, flooring surfaces glued to the slab may loosen. To prevent this, a 6-mil polyethylene vapor retarder with joints lapped at least 6" must be placed between the slab and the subbase. Standard polyethylene may be used. However, cross-laminated polyethylene is more durable. In either case, workers should be warned not to puncture the membrane when placing the concrete.

One disadvantage of a vapor retarder is that it forces moisture in the fresh concrete to escape through the exposed top surface. This can cause shrinkage cracks in the slab surface, as well as other problems. For this reason, it is sometimes recommended that concrete not be placed directly on the vapor barrier. Instead, a 3" thick layer of sand can be spread over the vapor barrier and compacted. The concrete can then be placed over the sand.

Radon Control Radon is a colorless, odorless radioactive gas given off by some soils and rocks. In some parts of the United States, the seepage of radon into houses poses a health threat (see Chapter 10).

Houses built in areas with radon seepage must be built to resist radon entry. In some houses, the combination of a granular subbase and a carefully installed vapor barrier is enough. However, where concentrations are very high, stronger methods are needed.

REGIONAL CONCERNS

Radon Hazard Areas The Environmental Protection Agency (EPA) has developed a map showing which areas of the country have the highest radon risk. This map is in the IRC. Broadly, states located in a band from the Southeast through Texas are least likely to have radon problems. Alaska, Hawaii, and portions of the Pacific Northwest are also considered low-risk areas.

Go to **glencoe.com** for this book's OLC for more information about regional concerns.

One such method is the sub-slab ventilation system shown in **Figure 11-7**. This is called a *passive venting system* because no fans are involved. An *active venting system* uses one or more fans to move the air.

Placing the Concrete Concrete for the floor slab and bearing-wall footings should be made with durable, well-graded aggregate. It must have a compressive strength of at least 2,500 psi. The concrete should be workable so it can be placed without developing large air pockets (honeycombing) or excess water on the surface. However, too much water should not be added to the concrete just to make it easier to place. This reduces its strength. If necessary, the proportion of fine and coarse aggregate should be **adjusted** to obtain a more workable mix. Another way to increase workability is to add an admixture to the concrete (see Chapter 8, "Concrete as a Building Material").

Concrete should not drop more than approximately 4' to the ground as it is delivered by the ready-mix truck, as shown in **Figure 11-8**. A greater drop can cause large

JOB SAFETY

PLACING CONCRETE SAFELY When placing concrete, always be sure that the operator of the concrete truck or the concrete pumper can communicate clearly with other workers. The operator should be able to see where the concrete is being placed. Proper use of hand signals will ensure that the flow of concrete can be stopped quickly when necessary. Always discuss hand signals with the operator *before* the concrete starts to flow.

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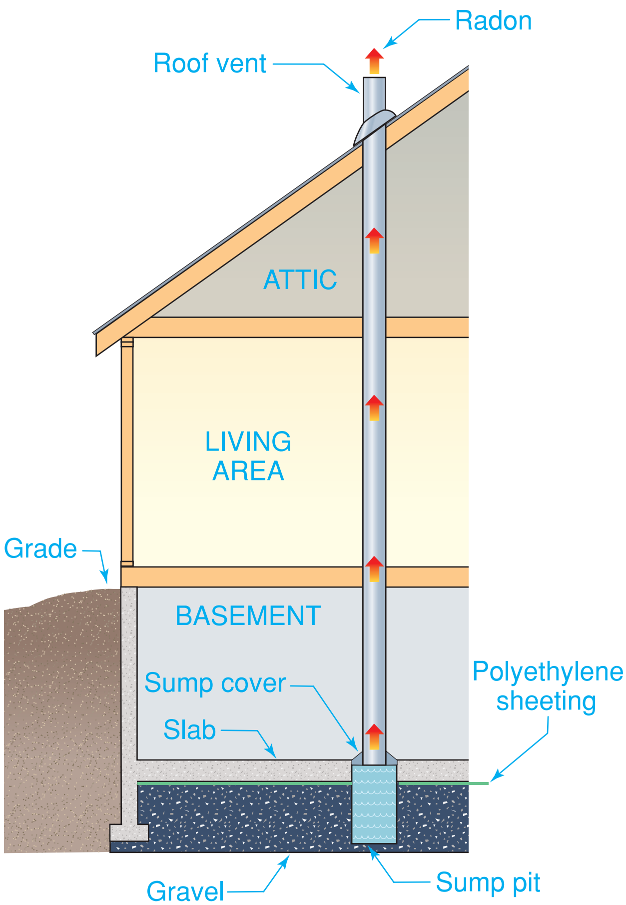


Figure 11-7 Radon Control System
Passive Venting One method of venting radon gas from beneath a slab.

Figure 11-8 Placing Concrete
Maximum Chute Height The end of the concrete chute should be within approximately 4' of ground level.

aggregate to settle unevenly, weakening the concrete. Extension chutes, temporary ramps, or methods such as pumping prevent this problem. After placing, the concrete should be made to settle by vibrating, tamping, or spading. Then it should be finished. The steps in finishing the surface will depend upon the floor finish specified. You will learn more about this in Section 11.2.

Reading Check

Explain *When placing the concrete, why is it important not to add too much water?*

Other Types of Flatwork

What is concrete used for?

There are other types of concrete slabs besides ones that are used as a foundation. Basements typically include a concrete floor slab. The slab is placed after all improvements, such as sewer and water lines, have been connected. Concrete is also often used for walks and driveways, especially where snow removal is important.

Basement Floors

Basement floor slabs should be no less than 3½" thick and should slope toward a floor drain. There should be at least one drain in a basement floor. For large floors, two drains may be required.

When concrete is placed in an enclosed area, such as a basement, the foundation walls serve as forms. However, the concrete still must be leveled to the correct thickness. This is done by means of rail-like devices on which a screed rides, as shown in **Figure 11-9**. A **screed** is a long, straight length of metal or wood that is used to "strike off" (level) the concrete. The screed is pulled by hand across the top of the rails. At the same time, the screed is moved back and forth in a sawing motion. The rails are made of sections of 1" pipe set on stakes driven into the subgrade. The pipes used as rails are called screed strips. The stakes are driven deep enough so that when the pipes are set on them, the tops of the pipes will be at the level desired for the surface of the slab. After screeding, the pipes and stakes are removed. A float is then used to pack concrete into any gaps. You will learn more about this in Section 11.2.

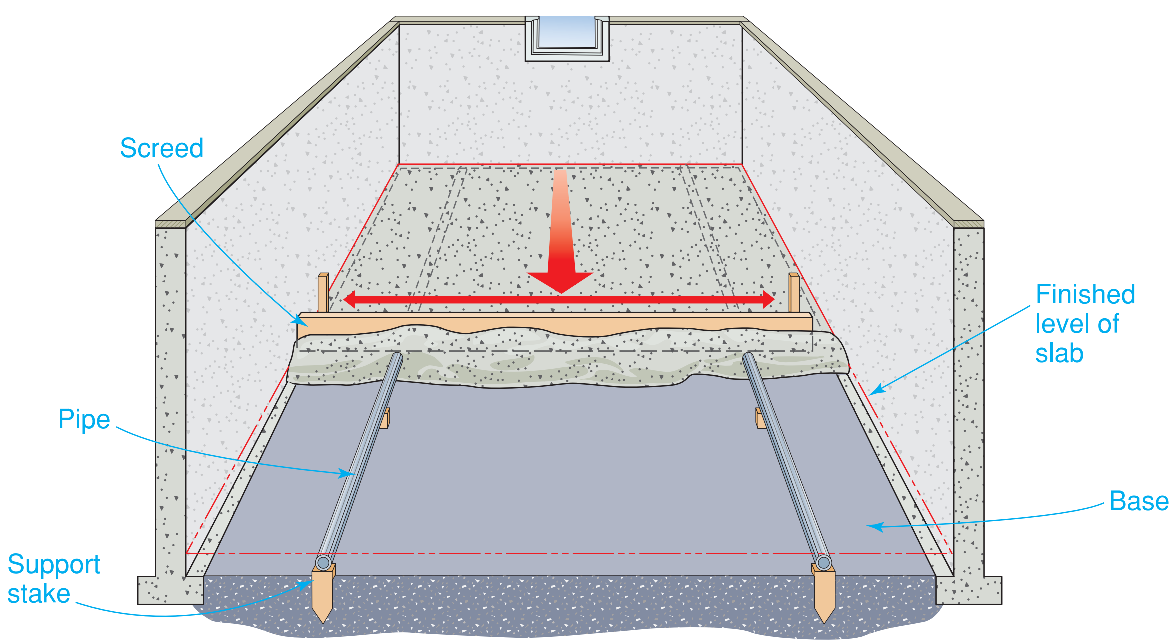


Figure 11-9 Screeding Concrete

Maintaining Thickness Metal pipes may be used to guide the screed when leveling a basement floor.

Driveways

The grade, width, and radius of curves in a driveway are important when establishing a safe entry to the garage. Driveways that have a grade of more than 7 percent (7' rise in 100 lineal feet) should not be covered with gravel because the gravel will gradually wash away. Concrete or asphalt is often used instead. A common type of concrete driveway is the full-width slab. The concrete should be given a broom finish to prevent both cars and people from slipping. It should also be slightly crowned. This means it should be slightly higher at the center than at the edges. This allows it to drain properly.

A gravel base is not ordinarily required on sandy, undisturbed soil. If the area has been recently filled, the fill, preferably gravel, should settle first and be well tamped. A gravel base should be used on all other soils. The concrete should be about 5" thick, and a vapor barrier is not required. Side forms are often built of 2×6 boards. These members establish the elevation and alignment of the driveway. They are also used to support the screed used to strike off the concrete.

Though not required, the addition of 6×6 wire fabric reinforcing reduces pavement cracking. Expansion joints with asphalt-saturated felt strips inserted should be used where the driveway joins the public walk or curb and at the garage slab. They should also be used about every 40' on long driveways. Concrete containing an air-entraining agent should be used in areas having severe winter climates. Air-entraining produces tiny air bubbles that help the concrete resist damage during freeze/thaw cycles.

Sidewalks and Walkways

Concrete sidewalks are constructed in much the same way as concrete driveways. They should not be poured over filled areas unless the fill has settled and is well tamped. This is especially true of areas near the house after basement excavation backfill has been completed.

Minimum thickness of concrete over normal undisturbed soil is usually 4". Control joints should be used and spaced on 4' centers. A *control joint* is a joint that helps to minimize random cracks in a concrete slab. By creating a slightly weakened area, it encourages a crack to form in a straight line, rather than across the concrete in an irregular line. Note that it does not prevent the concrete from cracking. It simply controls the location of the crack. An expansion joint may also be required for sidewalks. An *expansion joint* is a gap between portions of concrete that is filled with a flexible material. The concrete is thus able to expand and contract without damage to itself or to adjacent surfaces.

When slopes to the house are greater than 5 percent, a walkway should have steps, as shown in **Figure 11-10**. Steps make the walkway easier to use. The riser (vertical portion) of each step is sometimes formed by 2×6 lumber. In effect, each platform of a stepped walkway is formed like an individual slab.

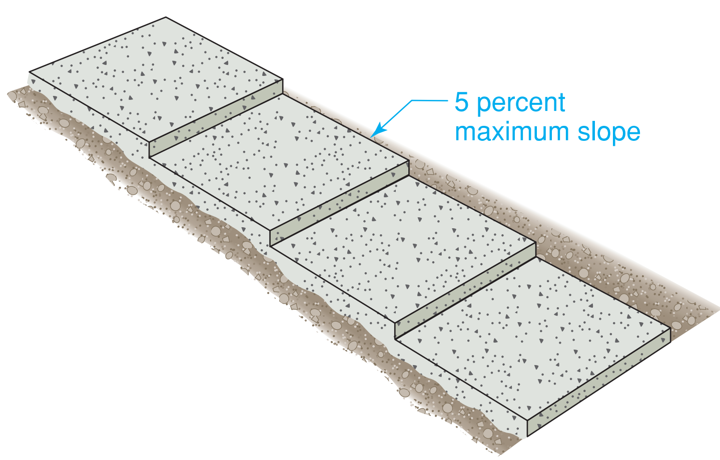


Figure 11-10 A Steep Walkway
Steps for Safety Steps in a steep walkway make it safer and more comfortable to use.

Estimating and Planning

CERTIFICATION PREP

This estimating and planning exercise will prepare you for national competitive events with organizations such as SkillsUSA and the Home Builder's Institute.

Concrete for Flatwork

Calculating Volume

The volume of concrete needed for flatwork is based on the size of the area covered and the thickness of the slab. The result is expressed in cubic yards.

1. To calculate the amount of material required for the basement floor of the home shown in the floor plan below, first figure the area of the slab. The house measures 26' × 40', so the total area of the basement slab will be 1,040 square feet.
2. The floor will be 4" thick. **Table 11-1** shows that at a thickness of 4", one cubic yard of concrete covers 81 sq. ft. To calculate the total amount of concrete required, divide the total slab area (1,040 sq. ft.) by the number of square feet covered by one cubic yard (81):

$$1{,}040 \div 81 = 12.39$$

If you round this off, you will need 13 cu. yds. of concrete. When estimating, you should always round up.

Another way to calculate the volume of concrete is to use the following formula:

$$\textbf{length in feet} \times \textbf{width in feet} \times \textbf{thickness in feet} \div 27 = \textbf{cubic yards}$$

To use the formula, each dimension must be in the same unit. For example, if you calculate the volume of concrete for a slab that is 20'-6" long, 10' wide, and 4" thick, convert all dimensions to feet, using decimal equivalents:

$$20.5' \times 10' \times 0.33' = 67.65 \text{ cu. ft.}$$

Then divide by 27 to obtain cubic yards:

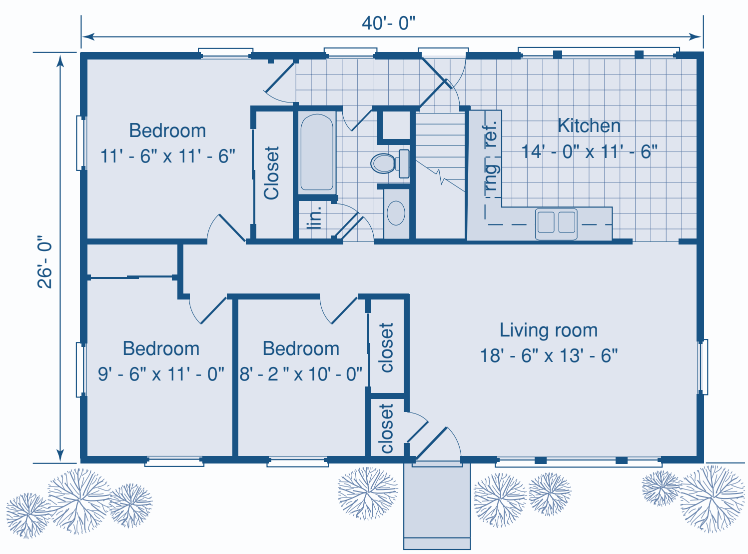
$$67.65 \div 27 = 2.50 \text{ cu. yds., or } 2\tfrac{1}{2} \text{ cu. yds.}$$

Estimating on the Job

Using Table 11-1, estimate the number of cubic yards of concrete needed for a basement floor that measures 20' by 30' and is 4" thick. Assume that 1 cubic yard of concrete can be placed in .43 hours. Estimate the time it would take to place the concrete.

Table 11-1: Estimating Materials for Concrete Slab

Material	
Thickness (inches)	Square Feet from One Cubic Yard
2	162
3	108
4	81
5	65
6	54



Section 11.1 Assessment

After You Read: Self-Check

1. What is concrete flatwork?
2. Why is it important to compact the subgrade in lifts?
3. What is the purpose of the subbase?
4. What is the formula for calculating cubic yards of concrete?

Academic Integration: Mathematics

5. **Using Formulas** Calculate the cubic yards of concrete required for the basement floor for a home that is 36' wide, 45' long, and 6" thick.

   Math Concept A formula is an equation that gives the relationships between the numbers in a group of numbers. A letter or word is often given to represent the value. In this chapter, you are given the following formula to calculate volume in cubic yards: Volume = (length in feet × width in feet × thickness in feet) ÷ 27 = cubic yards.

Go to **glencoe.com** for this book's OLC to check your answers.

Section 11.2 Finishing Flatwork

Finishing a Slab

What is the first step in finishing flatwork?

A flatwork surface, such as a floor, driveway, or sidewalk, must be finished. Finishing is a multiple-step process that levels the concrete and gives it a surface that will suit the intended use. A basement or foundation slab, for example, is given a very smooth finish. This makes the concrete easy to clean and allows finished floors to be attached directly to the surface. A broomed, non-slippery finish is best for sidewalks, while a somewhat coarser surface suits driveways. Various decorative finishes are also available.

Steps in Finishing

Finishing is a multiple-step process that may includes screeding, bullfloating, edging, jointing, floating, and troweling. Some steps, such as jointing, are not required on every job.

Screeding The first step in finishing any flatwork is screeding. A hand-operated screed and the method of using it are shown in **Figure 11-11**. The concrete is *struck off* just after it is placed in the forms. The screed rides on the edges of the side forms or on wood or metal strips set up for that purpose. Two people move the screed along the slab, using a sawing motion. Screeding may

Figure 11-11 Hand Screeding
Team Effort Screeding a concrete slab.

also be done with mechanical equipment, as shown in **Figure 11-12**. It leaves a level surface with a coarse finish.

Bullfloating Bullfloating makes the concrete surface more even with no high or low spots, as shown in **Figure 11-13**. A **bull float** is a wide, flat metal or wood pad that is pushed back and forth over the concrete to make the surface even. A long handle enables the worker to reach every area of the slab. A similar tool, called a *darby*, has a somewhat shorter handle.

Figure 11-12 Power Screeding
Speeding the Work A power screed is often used to smooth large expanses of concrete.

Figure 11-13 Bullfloating
Long Reach Bullfloating is done from the edges of the installation.

Bullfloating is done shortly after screeding, while the concrete is still wet enough to allow a slight paste of mortar to be brought to the surface. However, there must be no water visible on the concrete. Otherwise, an excess amount of fines and moisture will also come to the surface. This is one of the principal causes of defects. Among other problems, it causes fine hairline cracks (*crazing*) or a powdery material (*dusting*) on the surface. Only enough bullfloating should be done to remove defects and to bring enough mortar to the surface of the slab to produce the desired finish.

Edging and Jointing When the sheen has left the surface and the concrete has started to stiffen, other finishing operations can be done. Edging produces a rounded edge on the slab to prevent chipping or damage, as shown in **Figure 11-14**. The edger is run back and forth, covering coarse aggregate particles.

Immediately following edging, larger slabs are jointed, or grooved. Sometimes shrinkage stresses are present in the slab as a result of temperature changes or dryness. These stresses can cause the concrete to crack. Joints reduce the thickness of the slab and cracks are then likely to occur only at these weakened points. When the concrete shrinks, these joints open slightly, preventing other uneven and unsightly cracks. A jointing tool is used to cut the control joints about ¾" deep in the slab. The joints should be perpendicular to the slab's edge. To ensure straight joints, it is good practice to guide the jointer with a straight 1×8 or 1×10 board, as shown in **Figure 11-15**. A crooked joint detracts from the appearance of the finished slab.

Hand Floating In some cases, an additional floating step is done, using wood or metal floating trowels, or floats. Hand floating further evens the surface of the concrete. It also compacts the surface mortar in preparation for the next finishing steps. It produces a very even surface with a light texture. Hand floating also removes any ridges left by jointing tools. Aluminum or magnesium floats must be used when hand floating air-entrained concrete because wood floats stick to the concrete surface. If floating is the last step in finishing, it may be necessary to float the surface a second time after the concrete has hardened slightly.

Troweling For a dense, smooth finish, floating is followed by troweling with a steel trowel, as shown in **Figure 11-16**. For large areas, a power trowel is used instead of a hand trowel, as in **Figure 11-17**. Troweling cannot be started until the concrete has hardened enough to prevent fine material and water from working to the surface. In fact, troweling should be planned carefully.

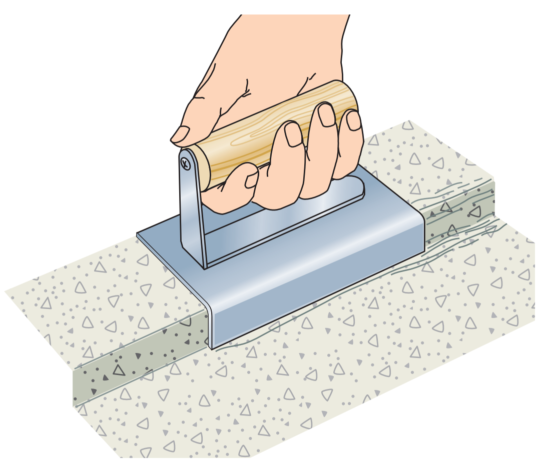


Figure 11-14 Edging a Slab
Rounded Edge An edger smoothes the edge of a slab.

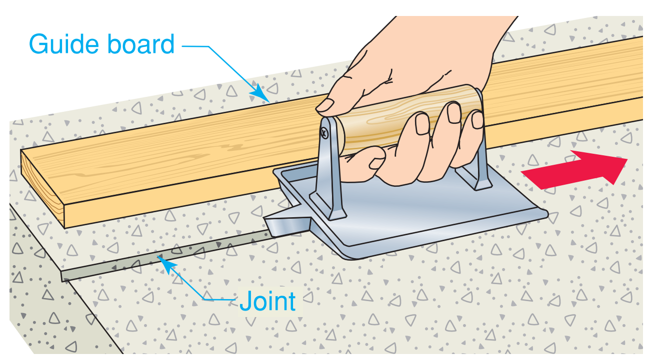


Figure 11-15 Jointing a Slab
Stress Relief A jointer is guided by a board or some other straight edge.

A surface that is troweled too early will not be durable. A surface that is troweled too late will be difficult to finish properly.

Hand or power troweling should leave the surface smooth, even, and free of marks and ripples. For a fine-textured surface, the first troweling is immediately followed with a second. In this second operation, the trowel is held flat and passed lightly over the concrete with a circular motion.

For a hard steel-troweled finish, the second troweling should be delayed until the concrete has become hard enough to make a ringing sound under the trowel. In hard steel-troweling, the trowel is tilted slightly. Heavy pressure is applied to compact the surface.

Another type of finishing tool is called a *fresno*, a steel trowel that it is attached to a long handle. It enables concrete finishers to

Figure 11-16 Hand Troweling
Smoothing a Surface Hand troweling a concrete slab.

Figure 11-17 Power Troweling
Super Smoother Power troweling a concrete slab.

Builder's Tip

USING KNEEBOARDS When hand-troweling or floating a large surface, kneeboards (or kneeling boards) may be used. Kneeboards measure about 12" by 24" and are placed on the concrete. The kneeboard supports the knees and feet of the finisher. It enables the finisher to move over the slab without leaving any marks on the concrete.

Figure 11-18 Using a Kneeboard

Figure 11-19 Stamped Concrete

Brick Pattern This concrete was colored and stamped with a pattern shortly after it was placed.

trowel the concrete without having to use kneeboards. A **kneeboard** distributes the weight of a finisher over the surface of the concrete, as shown in **Figure 11-18**.

However, the finisher cannot put as much pressure on a fresno as on a hand trowel. Therefore, a concrete surface finished with a fresno will not be as dense as concrete finished by hand or power troweling.

Special Finishes

Concrete can be given a color, a pattern, or a texture. This is done after the concrete has been placed but before it has cured. Patterns come from metal stamps that are pressed into the wet concrete, as shown in **Figure 11-19**. Colors come from various types of masonry dyes. In some cases, small, smooth pebbles can be scattered into the fresh concrete after bullfloating. They are pressed into place during later finishing operations.

A *broom finish* roughens the surface of the concrete slightly so that it will be more slip-resistant. To create the finish, a stiff bristle broom can be dragged over the surface in parallel strokes. This should be done after bleed water is completely gone from the surface. Brush strokes should be perpendicular to the grade. A *rubbed finish* creates the opposite effect. Shortly after the concrete has hardened and the forms have been removed, the surface is rubbed with abrasives to create a uniform surface that is very smooth. A *salt finish* is created by broadcasting rock salt (a type of very coarse salt) onto fresh concrete. A roller is then used to press the salt into the surface. The salt should be washed away after the concrete has set. This leaves a surface filled with shallow, angular indentations.

Curing Flatwork

After finishing, the concrete should be kept moist for at least two days. This ensures that hydration will continue. It also improves the concrete's strength. When the finished floor is to be exposed concrete, at least five days of moist curing are required. Burlap, canvas, or a waterproof concrete curing paper may be used to cover the floor slab during this period. If burlap or canvas is used, it should be kept wet by sprinkling it with water. Curing should begin as soon as the concrete is hard enough to make damage unlikely. Chemicals can also be used to coat concrete for curing. By slowing the rate at which moisture leaves the concrete, they help to increase its strength.

When the concrete has cured enough to withstand foot traffic, wall plates can be laid out and construction can continue.

Temperature Extremes Problems can be caused in concrete by temperature extremes that occur in the early stages of curing. This is because so much surface area is exposed.

Placing concrete in unusually hot weather can reduce its strength. Hot conditions also encourage workers to add more water to the mix, which further reduces its strength. In hot weather, the water and aggregates should be kept as cool as possible before being mixed with the cement. Forms, rebar, and the subgrade should be cooled by sprinkling them with water just before the concrete is placed. In some cases, it may be wise to place the concrete early in the morning, or even at night, to avoid very hot temperatures. Moist curing is particularly important under these conditions and should be started as soon as possible.

In moderately cold weather, the heat of hydration is usually enough to prevent damage. However, concrete placed in temperatures below freezing can suffer a loss of strength unless protected. In fact, if concrete is frozen shortly after being placed, it can lose up to 50 percent of its strength. Concrete can be protected by placing it in insulated forms or by covering it temporarily with insulation. High-early strength, air-entrained, and low-slump concrete can also be used to counteract such conditions.

Section 11.2 Assessment

After You Read: Self-Check

1. What is the purpose of a bull float?
2. What defects can be caused by bullfloating too soon?
3. When is a concrete slab ready for jointing and edging?
4. What are kneeboards used for?

Academic Integration: English Language Arts

5. **Imperative Mood** In English verbs, the *indicative mood* is used to show something, while the *imperative mood* is used to give commands. The unstated subject of an imperative sentence is "you." The street sign "STOP" and the phrases "Come here" or "Don't do that" are examples of imperative sentences. Directions are often given in the imperative mood. Use your own words to write a brief description of two steps of the finishing process. Use the imperative mood.

   Example:
   Indicative mood: "The concrete should be kept moist for at least two days."
   Imperative mood: "Keep the concrete moist for at least two days."

Go to **glencoe.com** for this book's OLC to check your answers.

CHAPTER 11

Review and Assessment

Chapter Summary

Section 11.1

Concrete foundation slabs are often used in warm or mild climates to provide a foundation and a subfloor for houses. Proper preparation of the subgrade and subbase are important to a high-quality job. Slabs are more prone than foundation walls to being damaged by temperature extremes.

Section 11.2

Finishing a slab is a process of preparing the surface for various end uses. After the concrete is placed, the excess is screeded off the slab. After any water has disappeared, bullfloating, edging, jointing, floating, and troweling can take place.

Review Content Vocabulary and Academic Vocabulary

1. Use each of these content vocabulary and academic vocabulary words in a sentence or diagram.

Content Vocabulary

- concrete flatwork (p. 294)
- frost depth (p. 294)
- monolithic slab (p. 295)
- independent slab (p. 295)
- lift (p. 298)
- subgrade (p. 298)
- fines (p. 299)
- screed (p. 301)
- bull float (p. 305)
- kneeboard (p. 308)

Academic Vocabulary

- layer (p. 298)
- occurs (p. 298)
- adjusted (p. 300)

Speak Like a Pro

Technical Terms

2. Work with a classmate to define the following terms used in the chapter: *frost heave* (p. 295), *power tamper* (p. 298), *plastic* (p. 299), *struck off* (p. 304), *fresno* (p. 307), *broom finish* (p. 308), *rubbed finish* (p. 308), *salt finish* (p. 308).

Review Key Concepts

3. Define the two types of foundation slabs.

4. Describe various types of slab reinforcement.

5. Summarize the steps in placing a slab.

6. List two forms of flatwork other than foundations.

7. Identify the tools needed to finish flatwork.

8. Illustrate how temperature extremes affect fresh concrete.

Critical Thinking

9. Synthesize How does metal reinforcement strengthen a concrete slab?

Academic and Workplace Applications

STEM Mathematics

10. Slope/Intercept Form Calculate the slope of a regular concrete wheelchair ramp that is 10 feet long. The bottom of the ramp is horizontal to the ground and the top of the ramp is 4 feet from the ground.

Math Concept Slope is the measure of a line's slant. Slope is given by the ratio of rise (vertical movement) to run (horizontal movement).

$$\text{Slope} = \frac{\text{rise}}{\text{run}}$$

Slope is often represented as a fraction. The fraction can be reduced to lowest terms. A horizontal line and a vertical line both have no slope (the rise over run is $\frac{0}{0}$). If a ramp is three feet high after you have gone six feet up the ramp, the slope of the ramp is $\frac{3}{6}$. Reduced to lowest terms, the slope is $\frac{1}{2}$.

Step 1: Substitute the appropriate numbers for rise and run.

Step 2: Reduce the fraction to lowest terms.

21st Century Skills

11. Communication Skills: Flow Charts A flow chart is a type of visual aid that represents a system or a process. Flow charts often use symbols, pictures, or other graphic elements to represent actual steps or things. For example, you might use the arrow symbol to indicate that one task should be completed after another task. You might use a picture of a tool or a color to indicate who might be performing a particular task. Imagine that you are supervising a team of three finishers, Jude, Frederick, and Sita, who all speak different languages. Use a graphics program or art materials to create a one-page flow chart that shows the steps they must follow when finishing a basement floor with a fine-textured surface. Assign each worker specific tasks.

STEM Science

12. Frostline The colder the climate, the deeper the frost depth. However, different factors, including geothermal energy (energy from the earth) can affect the frostline. What is the frost depth in your area?

Starting Hint Consult local building codes.

Standardized TEST Practice

CERTIFICATION PREP

Multiple Choice

Directions Select the word, phrase, or amount that best answers the question.

13. According the Environmental Protection Agency, which state is considered a low-risk state for radon risk?

a. Texas
b. Florida
c. Hawaii
d. Georgia

14. What is the minimum possible thickness that is recommended for basement floor slabs?

a. 1"
b. 3"
c. 1'
d. 3'

15. Which type of finish is best for sidewalks?

a. salt finish
b. broomed finish
c. rubbed finish
d. fresno finish

TEST-TAKING TIP

Reread all questions and answers containing measurements, abbreviations, or symbols. Make sure you have selected the answer with the correct symbol.

*These questions will help you practice for national certification assessment.

UNIT 3
Hands-On Math Project

Checking for Square

Your Project Assignment

One of a carpenter's most important jobs is to lay foundations square. In this project you will determine if a basketball court, volleyball court, or soccer field near your home is laid square.

- **Research** the regulation size for a basketball court, volleyball court, or soccer field.
- **Interview** a local carpenter about tools and processes for measuring and checking for square.
- **Measure** the length and width of the court or field, then predict and measure the diagonal.
- **Use** the 3-4-5 method to check the square area.

Applied Skills

Your success in carpentry will depend on your skills. Some skills you might use include:

- **Research** the standard sizes for athletics courts and fields.
- **Locate** and interview a local carpenter about measuring and checking for square.
- **Explain** the purpose of the 3-4-5 method.
- **Compare** calculated length with measured length.
- **Create** a sketch of a court or field with clearly labeled dimensions.

Math Standards

Measurement: understand measurable attributes of objects and the units, systems, and processes of measurement

Geometry: apply appropriate techniques, tools, and formulas to determine measurements

Geometry: analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships

NCTM National Council of Teachers of Mathematics

The Math Behind the Project

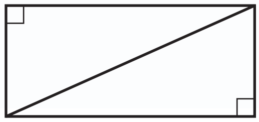
The traditional math skills for this project are geometry and measurement. Remember these key concepts:

Geometry

The Pythagorean theorem states that the sum of the squares of the sides of a right triangle is equal to the square of the hypotenuse. This is expressed as the equation $a^2 + b^2 = c^2$. To find the length of the hypotenuse (c), we take the square root of both sides of the equation:

$$\sqrt{a^2 + b^2} = c$$

The diagonal of basketball court divides it into two right triangles. The diagonal is the hypotenuse of the triangles.



Units of Measurement

When we solve for the equation above using measurements in feet, our answer will often contain a decimal. We need to convert the decimal to inches and fractions of an inch. First multiply the decimal by 12 to convert the decimal to inches. Then multiply the decimal from this calculation by 16 to convert it to $^{1}/_{16}$ of an inch.

For example, if a court is 24' wide and 54' long, we can calculate the length of the diagonal in feet, inches, and fractions of inches using the following steps:

1. Use the Pythagorean theorem to calculate the diagonal.	$\sqrt{24^2 + 54^2} = 59.093$ ft
2. Multiply the decimal by 12 to convert it to inches.	$12 \times .093$ ft. $= 1.116$ in.
3. Multiply the decimal from the above step by 16 to convert it to $^{1}/_{16}$ of an inch. Round.	$16 \times .116 = 1.856 \approx 2$
5. Write the total as inches and feet. Reduce the fraction if possible.	59 ft., $1\frac{2}{16}$ in. $=$ 59 ft., $1\frac{1}{8}$ in.

To convert inches and fractions of inches to a decimal, reverse the steps shown above.

Project Steps

Step 1 Research

- Research the regulation size of a basketball court, volleyball court, and soccer field.
- Determine if the courts or field at your school or in your neighborhood are regulation.
- Contact the local of the United Brotherhood of Carpenters and Joiners of America. Locate a local carpenter who is available for an interview.
- Write interview questions about methods of checking for square.

Step 2 Plan

- Select the court or field you will check. If no court is available, choose another rectangular area, such as a meeting room or parking lot.
- Sketch the area and indicate which dimensions you will measure.
- Choose a measuring tool, such as a measuring tape, a rigid ruler, or a scrap-lumber measuring stick.
- Interview the carpenter you located. Take notes.

Step 3 Apply

- Measure the length and width of the area to the nearest $^1/_{16}$ of an inch. Mark these on your sketch.
- Use the Pythagorean theorem to predict what the diagonal must be if the area is a perfect rectangle. Convert fractions of inches to decimals. Then use the equation $\sqrt{a^2 + b^2} = c$ to solve for the diagonal (c). Convert the decimal in your answer to sixteenths of an inch.
- Measure the diagonal. If it is longer or shorter than your prediction, the corners are not exactly 90°.
- Check the court for square again, this time using the 3-4-5 method. Start in one corner. Measure down one side 3 feet and down the other side 4 feet. Then measure the diagonal line between these two points. If the court is square, how long should the diagonal be?
- Compare the results of your two methods of checking for squareness. Did they yield the same result–square or not square? If not, recheck your measurements and calculations.

United Brotherhood of Carpenters and Joiners of America

Mission: To represent and offer training to North America's carpenters, cabinetmakers, millwrights, piledrivers, lathers, framers, floorlayers, roofers, drywallers, and workers in forest-products and related industries.

Go to **glencoe.com** for this book's OLC for more information on this organization.

Step 4 Present

Prepare a report combining your research, calculations, and measurements using the checklist below.

PRESENTATION CHECKLIST
Did you remember to…
✓ Demonstrate the research you conducted? .
✓ Discuss the tools and methods you used to measure?
✓ Explain the differences between measured length and calculated length?
✓ Use and present your sketch?
✓ Explain how you determined whether the court was square?

Step 5 Technical and Academic Evaluation

Assess yourself before and after your presentation.

1. Did you prepare well for the interview?
2. Did you calculate the diagonal correctly?
3. Was your sketch legible and neat?
4. Were your measurements accurate and precise?
5. Was your presentation clear and creative?

Go to **glencoe.com** for this book's OLC for an evaluation rubric and Academic Assessment

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Go to **glencoe.com** for this book's OLC to read an article titled "Special Report: Concrete." Write a summary of this article.